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Submitted by

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Cover and title page:

Graduate student Julie E. Greenberg places the fingers and thumb of her left hand on the mouth and neck of Research Specialist Joyce Manzella to demonstrate use of the Tadoma method of speechreading. This natural method of tactual communication is employed by deaf-blind individuals who have received special training in its use. In Tadoma, the hand of the "receiver" is placed on the face and neck of the "sender" so that the thumb rests lightly on the lips, and the fingers fan out over the face and neck. By monitoring various actions associated with speech production (e.g., lip and jaw movements, airflow at the mouth, and vibrations on the neck), an experienced Tadoma user is able to comprehend conversational speech with a high degree of accuracy. Research on the Tadoma method has provided valuable background information for the development of synthetic tactile devices for the deaf and deaf-blind. See page 293 for a further description of this research which is being carried out in RLE's Sensory Communication Group.

Our special thanks to the following staff members of the RLE Communications Group for their substantial contributions: Mary J. Ziegler for editing and scanning; Mary S. Greene for formatting, proofreading, and preparation of the publications and personnel chapters; Rita C. McKinnon for proofreading, and Markuené A. Sumler for formatting. We also want to thank David W. Foss, Manager of the RLE Computer Facility, for his time and technical assistance.

We thank the faculty, staff, and students of RLE for their generous cooperation.

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1.7.3 Evaluation of Practical Aids

Three new subjects have joined our field study of tactile-aid users, bringing the total number of subjects to eight. During the current year, six of the eight subjects visited our laboratory for evaluations of their speechreading performance with the Tactaid VII. Data are now available from three separate testing sessions with one subject (JL), two testing sessions with two subjects (RM, RS), and one session with each of the remaining subjects. The evaluations have been concerned primarily with assessing speechreading ability with and without tactile devices, as well as with measuring discriminability of simple speech segments through the use of tactile devices by themselves. Thus far, tactile devices employed in the study include Tactaid VII (which all subjects in the field evaluation have received), Tactaid II (tested only on three of the subjects who had used the Tactaid II prior to Tactaid VII), and a high-performance single-channel vibrator (Alpha-M AV-6 Minishaker) employed only in laboratory testing.

Results of segmental discrimination tests conducted with Tactaid VII indicate that, averaged across subjects and across consonant and vowel pairs, performance is roughly 70 percent correct.[42] Additional data collected on one subject with Tactaid II showed that performance for both devices was approximately similar. Results of tests conducted for speechreading alone and speechreading in combination with a tactile device (using sentence and continuous-discourse materials) showed a range of performance across subjects. For example, for the reception of words in CUNY sentences, scores from all subjects ranged from 32 to 86 percent correct (averaging 53 percent) for speechreading alone and 29 to 93 percent (averaging 58 percent) for speechreading plus Tactaid VII. Of the six subjects for whom data are currently available on this task, improvements to speechreading with the use of Tactaid VII were observed for four subjects (ranging from 5 to 17 percentage points improvement), while two subjects have shown no improvements to speechreading of CUNY sentences with Tactaid VII thus far. Data from three subjects tested with Tactaid II (as well as with Tactaid VII) on this task indicate greater improvements to speechreading (by approximately 8 percentage points) when using Tactaid II compared with Tactaid VII. Some preliminary data obtained on three subjects for speechreading of CUNY sentences with the Minishaker indicate that the benefits provided by this device are comparable to those observed with Tactaid II. The results of a questionnaire assessing subjects' use of tactile devices indicate that most prefer Tactaid VII to Tactaid II. This is primarily because of the greater utility of Tactaid VII in detecting and recognizing environmental sounds in addition to the benefits it provides for speechreading.[43]

1.7.4 Continuation and Completion of Previous Work on Natural Methods of Tactual Communication

During the past year, we have published summaries of our work on the communication abilities of deaf-blind subjects who use various natural methods of tactual communication, including the Tadoma method of speech reception and tactual reception of fingerspelling and sign language.[44] A manuscript describing a series of experiments conducted to demonstrate improvements to speech reception through Tadoma using supplementary tactual information has also been published.[45]

1.8 Super-Auditory Localization for Improved Human-Machine Interfaces

Sponsor

U.S. Air Force - Office of Scientific Research
Grant AFOSR 90-0200

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[42] C.M. Reed, L.A. Delhorne, and N.I. Durlach, "Results Obtained with Tactaid II and Tactaid VII," *Proceedings of the Second International Conference on Tactile Aids, Hearing Aids, and Cochlear Implants*, eds. A. Risberg and K.-E. Spens (Stockholm, Sweden: Royal Institute of Technology, forthcoming.

[43] C.M. Reed and L.A. Delhorne, "Field Study of Deaf Adult Users of Tactaid II and Tactaid VII," Presentation made at the Annual Convention of the Association for Late Deafened Adults, Boston, Massachusetts, September 10-13, 1992.

[44] C.M. Reed, N.I. Durlach, and L.A. Delhorne, "Natural Methods of Tactual Communication," chapter in *Tactile Aids for the Hearing Impaired*, ed. Ian R. Summers, (Whurr Publishers Limited, 1992), pages 218-230; C.M. Reed, N.I. Durlach, and L.A. Delhorne, "The Tactual Reception of Speech, Fingerspelling, and Sign Language by the Deaf-Blind," *SID Digest* 102-105 (1992).

[45] C.M. Reed, W.M. Rabinowitz, N.I. Durlach, L.A. Delhorne, L.D. Braida, J.C. Pemberton, B.D. Mulcahey, and D.L. Washington, "Analytic Study of the Tadoma Method: Improving Performance through the Use of Supplementary Tactual Displays," *J. Speech Hear. Res.* 35: 450-465 (1992).

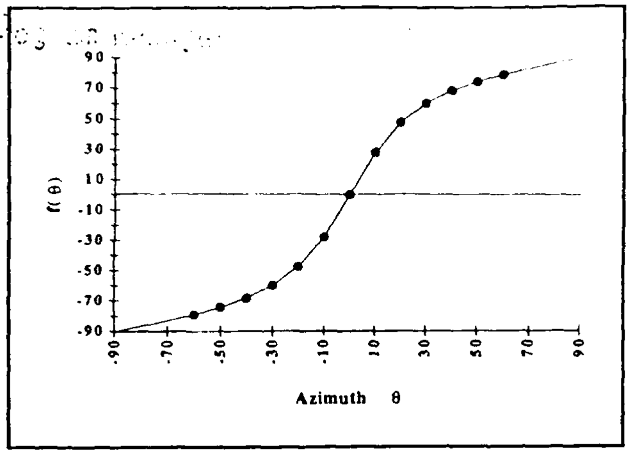

Figure 1.

Project Staff

Nathaniel I. Durlach, Eric M. Fuchs, Dr. Richard M. Held, Dr. William M. Rabinowitz, Yun Shao, Barbara G. Shinn-Cunningham, Min Wei

General background on this project was presented in pages 312-313 of the annual *RLE Progress Report Number 134.* During the past year, work has advanced along the following fronts.

1. Further localization identification experiments have been conducted using a transformation of the function relating head-related transfer function to azimuth such that azimuthal space is magnified in front and minified off to the side (see figure 1). As expected, results show increased resolution in the center and decreased resolution to the side. In addition, in contrast to our initial impression that no sensorimotor adaptation took place, i.e., that response bias failed to decay with an increase in exposure time, our results now clearly show consistent and substantial adaptation (in terms of both the direct effect and the negative after effect). However, results also indicate that the decrease in response bias over time is accompanied by a decrease in resolution over time. We are now studying these data as well as performing further experiments to determine the underlying causes of this phenomenon. Illustrative data showing the changes in both resolution and bias are presented in figure 2.

2. Further work on facilities development has included four projects. First, we have acquired, integrated, and tested a new analog hardware processor to cross-check the results already obtained with the convolvotron. Second, we have constructed a pseudophone (a head-worn microphone/earphone/amplification system with controllable geometry and acoustic characteristics) to provide us with a system in which localization cues are transformed acoustically rather than by signal processing and in which no head-tracking is required. Third, we have begun to develop a new head tracker based on inertial sensors for use with acoustical simulation systems. Fourth, and finally, we have developed an additional experimental set-up which allows us to simulate a sound source held in the hand so that we can make direct comparisons with classical studies on adaption in the visual sense using optical prisms and a manual pointing response.

3. Further work on the dissemination of our results has included talks at the Society for Information Displays, the First International Conference on Auditory Displays, and the Acoustical Society of America, as well as the publication of an article in *Presence* (Durlach et al., 1992).

1.9 Research on Reduced-Capability Human Hands

Sponsor

U.S. Navy - *Office of Naval Research*
Grant N00014-90-J-1935

Project Staff

Lorraine A. Delhorne, Nathaniel I. Durlach, Dr. Mandayam A. Srinivasan

General background on this project was presented in *RLE Progress Report Number 134* (pages 313-314). During the past year, attention has been focused on further data collection and data analysis for constrained-hand performance in a subset of the tasks previously used by the Navy in the TOPS teleoperator study (Smith and Shimamoto, 1991).

Although direct comparisons between the results of our tests and those contained in the TOPS project are difficult to interpret because of the many differences in the two testing situations (e.g., direct vision versus vision through a helmet mounted display, working in air versus working under water, etc.), our results suggest a number of important conclusions.

First, the results indicate that all tasks considered were essentially two-finger tasks. We say this because (1) the results obtained with two fingers were nearly as good as those obtained with more fingers (both for the real hands and for the teleoperator hands) and (2) we know from casual observ

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